Continuous Deflection Separation (CDS) for Sediment Control in Brevard County, Florida

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Abstract

In July 1997, Brevard County's Stormwater Utility Program installed a new type of trash and sedimentation control device called a Continuous Deflection Separation (CDS) unit. This was the first American installation to use the CDS technology, which was developed in Australia. After installation, autosamplers were placed upstream and downstream of the CDS unit and a year's duration of sampling data collected. Monitoring has shown that the CDS unit has provided an average 52% removal efficiency for total suspended solids and 31% removal efficiency for phosphorus.

Introduction

Stormwater sedimentation is a primary source of pollution to Florida's Indian River Lagoon. Suspended solids and turbidity reduce sunlight penetration in the lagoon which negatively impacts seagrass growth. Where land is available, detention ponds effectively reduce most of the suspended solids from stormwater flows. When land is not available, alternative, less effective, treatment methods must be used.

The CDS technology was initially developed in Australia to provide an effective method for trash and solids removal from stormwater flows. The screening action within the unit provides for 100% removal of trash and particles down to 4700 microns. In addition, the unique circular design creates centrifugal action within the round concrete box which propels suspended solids to the center of the box and down into the storage chamber.

Methods

The location chosen for the CDS unit installation was along a ditch at the north end of Brentwood Drive, south of Port St. John. The drainage basin for this location was 24.87 hectares (61.45 acres) in area. This basin has Type A soils along a sand ridge. The land uses are 24.87 hectares (6.7 acres) of roadway (US Highway 1), 8.04 hectares (19.87 acres) of industrial park, 9.47 hectares (23.39 acres) of vacant land, and 4.65 hectares (11.49 acres) of commercial property. The industrial area has a permitted stormwater system. A significant land feature is a 2.02 hectares (5 acre) dirt parking lot, 152.4 meters (500 feet) upstream of the site around a local restaurant. This parking lot has a steep slope and is composed of fine white base material. There is evidence of heavy silt buildup in the inlets and pipes downstream of this parking lot, along US 1.

There is an earthen ditch running eastward 76.2 meters (250 feet) upstream from the project location. At the project site, there is an existing 122 centimeter (48 inch) RCP driveway culvert in the ditch which discharges to a concrete channel running 152.4 meters (500 feet) eastward to the Indian River. The time of concentration to the site is 63 minutes, with a 1 O-year flow of 1,557.2 L/sec (55 cfs) and mean annual flow of 1,177.9 L/s (38.2 cfs). In Brevard County, the 10-year storm is 20.1 centimeters (7.9 inches) of rainfall and the mean annual storm is 13.97 centimeters (5.5 inches) of rainfall. There is no base flow at this location.

A diversion weir 68.58 centimeters (27 inches) tall is placed in front of the 122 centimeter (48 inch) culvert so as to divert flows over 254.8 L/sec (9 cfs) around the unit. In 18 months of observations, the water level has risen over the weir one time.

A 76.2 centimeter (30 inch) concrete pipe was constructed adjacent to the existing 122 centimeter (48 inch) pipe in order to divert flows to the CDS unit. The 76.2 centimeter (30 inch) pipe enters the CDS unit tangentially to start the circular flow within the unit.

The CDS unit consists of three circular, concrete chambers stacked on top of each other. The top chamber, where the water enters the unit, has a 1.524 meter (5 feet) inner diameter and is 188 centimeters (74 inches) tall. The middle chamber has a 2.44 meter (8 feet) inner diameter and is 127.54 centimeters (51 inches) tall. In the middle chamber is a 1.524 meter (5 foot) diameter stainless steel screen matching the walls of the top chamber. The screen has 4700 micron holes to filter larger materials. The bottom chamber has a 1.22 meter (4 foot) inner diameter by a 1.22 meter (4 foot) tall sediment sump.

Water enters the unit in a clockwise rotation. When the water passes through the screen, it flows counter-clockwise between the screen and outerwall until it reaches a 76.2 centimeter (30 inch) concrete pipe. This exit pipe is tangentially placed for smooth exit flows. The elevation of the exit pipe rises 96.52 centimeters (38 inches) from the lower chamber to the outflow channel downstream of the 122 centimeter (48 inch) culvert. This rise in elevation keeps the normal water level in the unit near the top of the second chamber at all times. There is no base flow at this location.

The top of the unit is flush with the surrounding ground and has a 0.91 meter (3 foot) square, lockable, stainless steel access cover. This feature allows for easy access with a vacuum truck for cleaning purposes.

The CDS unit was installed on July 17, 1997. Installation took two days with the precast structures. A large crane was required to lift the chambers into place. A 4.57 meter (15 foot) deep hole was excavated for the structure.

In conjunction with the CDS unit installation, County forces cleaned the ditch upstream of the unit. Two days later, a significant rainfall event occurred and 2,294 kilograms (6,600 pounds) of sediment from the upstream ditch wastrapped in the unit. After that storm, the ditch was reworked and sod was laid. The sod greatly reduced the volume of sediment washing into the unit.

Cleanouts were also performed on November 17, 1997, removing 626.84 kilograms (1,382 pounds) of sediment and 2.88 meters (34 cubic feet) of trash and debris, and again on May 6, 1998, with 998 kilograms (2,200 pounds) of sediment. The solids removed from the unit are taken to the Brevard County landfill for disposal. The volume of water stored in the unit is greater than the vacuum truck capacity, so decanting is performed on nearby sandy soils to avoid a second trip to the landfill for disposal.

Evaluation of the CDS Unit During Storm Events

The intent of the sampling was to evaluate the effectiveness of the CDS unit in removing pollutants from a storm event prior to discharging stormwater into the Indian River Lagoon.

Five storm samples were collected at the CDS unit between April 1998 and March 1999. The storm events occurred after dry periods ranging between 7 and 75 days. Protocol for this program dictated that if the sample collection devices (autosamplers) were triggered at intervals of less than three days between storms, the samples were to be discarded. This situation did not occur during the year, and near-drought conditions were observed in the sample area throughout most of the year-long monitoring program.

Rainfall was measured at the sampling site by a tipping bucket rain gauge, and additional rainfall data obtained from the Orlando Utilities Commission (OUC) power generating plant 5.6 km (3.5 miles) to the north of the CDS installation.

Review of the rainfall data collected indicates that the majority of the water passing through this BMP was from precipitation falling on the upland, 18.72 hectare (46.25 acre) watershed. The variation noted in both coverage and amount of rainfall helps illustrate the localized nature of the storms occurring along the Lagoon coastline. During this sampling period, water flowing off the drainage basin contributed much more flow through the CDS unit than would have been expected based on the rainfall recorded at the sample site.

Samples were collected through the use of automated storm water samplers; one at the inlet and another at the outlet pipe of the CDS unit. All samples, associated blanks, and duplicates were collected in accordance with our state-certified Comprehensive Quality Assurance Plan.

The stainless steel intake strainers for the samples were mounted on the reinforced concrete pipe, slightly off center bottom, and both angled away from the flow. This was to prevent the strainers from becoming silted over by sediments and allow collection of representative water samples. Flow rates during the storm events were measured initially utilizing water level meters (ISCO bubbler type) in conjunction with a 90-degree V-notch weir, but eventually replaced with a Doppler area-velocity flow meter which provides a more accurate flow assessment. Initially, two bubbler meters were installed with both bubbler tubes mounted on the upstream weir. However, this led to difficulties in estimating just when to trigger (time delay) the downstream sampler in order to collect samples from the same "plug" of water.

During the first three sample events, water levels recorded were correlated to flow, and the samples were manually composited to give a flow-weighted composite sample from each sampler. Both inlet and outlet sample sets were composited identically, in accordance with the EPA NPDES Stormwater Sampling Guidance Document (July 1992). Discreet samples were collected for the fourth and fifth events.

It was intended that the third sample event would include a mass balance calculation. The CDS unit sump was thoroughly cleaned utilizing a VAC-truck to ensure that the material collected was a result of the one storm to be evaluated. Inlet and outlet stormwater composite samples were again collected, with the addition of a sediment (Table 1) and water column sample from the sump. Sediment depths were measured at five locations; four from the corners of the lid opening and one in the center. Based on a depth of 13.21 centimeters, a sump diameter of 1.22 meters (4 feet) and an estimated 1,410.6 kg/m3 (88 lb/ft^3), (based on previous sediment weight evaluation), approximately 217.3 kilograms (479.2 pounds) of sediment was collected in the unit from storm three. Based on the concentrations measured, 126.07 grams (4.443 ounces) BOD 5, 33.587 grams (1.184 ounces) of metals, and 122.81 grams (4.33 ounces) of Total Kjeldahl Nitrogen (TKN) were removed.

Table 1. Sediment Chemical Analysis For Storm **#1**

Parameter	Sediment Grab	Grab Duplicate	Average Value	Detection Limit	Units
Arsenic	0.096	0.11	0.103	0.069	Mg/Kg
Barium	3.4	2.9	3.15	0.14	Mg/Kg
Benzo(b)fluoranthene	260	ND	250	240	Ug/Kg
BOD5	650	510	580	2.7	Mg/Kg
Cadmium	0.03	0.033	0.0315	0.014	Mg/Kg
Chromium	1.1	1.1	1.1	0.027	Mg/Kg
Copper	1.2	0.95	1.075	.0.027	Mg/Kg
Iron	220	260	240	0.55	Mg/Kg
Lead	2	2.2	2.1	0.041	Mg/Kg
Nickel	0.4	0.36	0.38	0.069	Mg/Kg
Silver	0.16	0.059	0.1095	0.014	Mg/Kg
Total Kjeldahl Nitrogen	450	680	565	37	Mg/Kg
Total Phosphorus	79	230	154.5	9.2	Mg/Kg
Zinc	14	14	14	0.27	Mg/Kg

Notes:
Equipment Blank Water Yielded ND for all listed analytes.
*The benzo(b)fluoranthene mean value was calculated with the RDL as the lower value for the duplicate.

Only parameters with values above detection limit are listed. Many others were tested below detection limits.

For this third sample event, the upstream, or intake flowmeter bubble tube was mounted on the 90-degree V-notch inlet weir, as it was for previous sample events. The downstream bubbler, however, was moved and attached to the downstream discharge pipe. This change was necessary to account for the lag time between when the first sampler received flow at the beginning of the storm, the time required to fill the sump with 8,115 liters (2,144 gallons), and discharge to flow past the second sampler several minutes later. The problem encountered with this revised setup was that the upstream V-notch weir used to determine the flow was overtopped, allowing flow around and over it, preventing an accurate flow measurement. This led to disparity in the estimation of actual flow through the unit. Due to the questionable flow measurements, it was not possible to calculate the mass balance.

For the fourth sample event, an ISCO Doppler area-velocity flow meter was mounted in the bottom of the outfall pipe of the CDS unit. Upon registering a water level rise of one inch, this unit triggered both upstream and downstream autosamplers. The autosamplers were synchronized, collecting a bottle set in each ISCO at the same time. With this methodology and placement, overtopping the weir, flow bypassing, and pressurization were no longer potential sources of error. Since the samplers now triggered only when the sump was full, it was also somewhat easier to accept the premise of "what went in, must have come out."

Appropriate trigger points were selected in orderto allow sufficient water depth forthe velocity meter probe to operate properly. We found that the Doppler area-velocity flow meter probes appear to function erratically when covered by less than one inch of water, and believe that measurements taken when the water was at this depth are suspect. Two-bottle sample sets were collected at sampler initiation, and at 1 O-minute intervals during the storm. During previous sample excursions, samples were manually cornposited. Due to a high suspended solids content, (heavy particles including sand) that rapidly settled in the sample container, it was questioned whether the composite samples were truly representative of the solids collected. Therefore, discrete two-bottle sets collected every 10 minutes were sent to the laboratory without being cornposited.

For the fifth sample event, two-bottle sample sets were again collected at sampler initiation, and at lo-minute intervals during the storm. As with the previous sample event, sample sets were not composited but sent for analysis as six individual, two-bottle sets. The sample bottles for bottle sets six were not collected due to insufficient water to cover intake strainers, as the storm was not of adequate duration to produce the last 1 O-minute sample. Because of numerous problems encountered in the previous storm event samplings, along with refinements in sampler setup and flow measurement, the fifth storm sample event is considered the most accurate to determine what pollutant reduction is provided by the CDS unit for that storm. The individual two-bottle sets showed the variation in pollutant loadings throughout the storm event and the corresponding removal under the varying loads. Unfortunately, this was the lowest flow storm encountered, which may account for higher than normal removal efficiency. Maximum flow was estimated to be only 136 liters/sec (2.16 gpm). The average pollutant reduction between inlet and outlet samples for this event was: BOD5 53%, COD 52.6%, TP 36%, TSS 56%, and Turbidity 74.8%.

Sample results are presented in Tables 2 through 4 for the five sample events. Storm event 2 showed a 23% reduction in turbidity, but no reduction in the other parameters. Storm 4 showed an increase in most parameter concentrations between inlet and outlet that could not be attributed to resuspension due to a full sump, since the sump had been cleaned prior to the third event. Data for these two storms are therefore suspect. For events 1, 3, and 5, the average removal efficiencies for those parameters that showed a reduction were: TSS 52%, Turbidity 46.9%, BOD 34.2%, COD 35%, and TP 30.6%

After each sample event, field observations were made of the appearance of the sample jars, each containing a water sample that had been collected at progressive ten-minute intervals throughout the storm flow. Outlet samples typically appeared to be less turbid than the corresponding inlet samples, and also had less sediment on their bottoms. An observation was also made of the water surface inside the CDS unit proper. There was typically a thick layer of floating grass and other vegetation, an oil sheen, glass and plastic bottles, plastic sheets and bits, seeds and nuts, sticks, and a surprising amount of Styrofoam cups and particles.

Table 2. Storm #1-#3 Test Results - Composite Samples

STORM 1	pH s u	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	220	180	28	150	1.4
CDS Outlet	7.4	110	100	23	110	1
Change	0.2	100	80	5	40	0.4
Percent Reduction	3%	50%	44%	18%	27%	29%

Maximum flow rate = 5.488 literslsec (87 GPM, 0. 19 cfs)
Storm Duration = 67 minutes
Rainfall @ OUC 0.254 cm (0. 1 inch), @ SITE not recorded

STORM 2	pH s u	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	8.4	350	440	8.2	20	0.86
CDS Outlet	8.2	350	340	8.2	20	0.86
Change	0.2	0	100	0	0	**0**
Percent Reduction	2%	0%	23%	0%	0%	**0%**

Maximum flow rate = 8.39 liters/sec (133 GPM, 0.3cfs)
Storm Duration = 68 minutes
Rainfall @ OUC 1.778cm (0.7 inch),.@ SITE 0.0762 cm (0.03 inch)

STORM 3	pH s u	Total Suspended Solids(mg/1)	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	300	110	12	71	1.3
CDS Outlet	7.6	150	86	8.2	53	0.95
Change	0	150	24	3.8	18	.35
Percent Reduction	0%	50%	21.8%	31.7 %	25.4	27%

Maximum flow rate = 149.75 liters/sec (2374 GPM, 5.29cfs)
Storm Duration = 113 minutes
Rainfall @ OUC 4.064 cm (1.6 inch), @ SITE 1.27 cm (0.5 inch)

Table 3. Storm #4 Test Results - Discrete Samples

Set 1 @ initiation	BOD5-Day (mg/1)	COD (mg/1)	pH (SU)	Total Phosphorous (mg/1)	Total Suspended Solids (mg/1)	Turbidity (NTU)
Inlet 1	2.1	2	8	0.32	690	99
Outlet 1	5.4	2	7.8	0.19	320	120
Change	+3.3	0	-0.2	-0.13	-370	+21
Percent Reduction/Gain	+61%	0*%	-3%	41%	-54%	+18%
Inlet 2	6.6	15	8.3	1.2	1400	1800
Outlet 2	7	18	8.4	0.94	1600	1000
Change	+0.4	-3	+0.1	-0.26	+200	-800
Percent +/-	+6%	+17%	+1%	-22%	+13%	44%
Inlet 3	6.7	25	8.2	1.2	830	530
Outlet 3	6.7	24	8.3	1.5	550	430
Change	0	-1	+0.1	+0.3	-280	-100
Percent Reduction/Gain	0%	-4%	+1%	+20%	-34%	-19%
Inlet 4	6.3	45	8.1	1.6	330	200
Outlet 4	NT	NT	NT	NT	NT	NT
Change	Na	Na	Na	Na	Na	Na
Percent Reduction/Gain	Na	Na t	Na	Na	Na	Na
Inlet 5	5.6	33	8	1.6	290	300
Outlet 5	6.4	30	8.2	1.6	170	260
Change	+0.8	-3	+0.2	0	-120	40
Percent Reduction/Gain	+13%	-9%	+2%	0%	41%	-13%
Inlet 6	6	39	7.9	1.6	220	120
Outlet 6	6.3	33	8.2	1.5	270	230
Change	+0.3	-6	+0.3	-0.1	+50	+110
Percent Reduction/Gain	+5%	-15%	+4%	-6%	+19%	+48%

Maximum flow rate = 60.30 liters/sec (956 GPM, 2.13 cfs)
Storm Duration = 55 minutes
Rainfall @ OUC 2.794 cm (1 .1 inch), @ SITE 0.006 cm (0.002 inch)

Table 4. CDS Storm #5 Test Results - Discrete Samples

	BOD5-Day (mg/1)	COD (mg/1)	pH (SU)	Total Phosphorous (mg/1)	Total Suspended Solids (mg/1)	Turbidity (NTU)
Inlet 1	4.6	68	7.8	0.23	49	16
Outlet 1	4.0	18	7.9 1	0.18	11	4.3
Change	-0.6	-50	+.1	-0.05	-38	-11.7
Percent Reduction/Gain	13%	74%	1 %	22%	78%	73%
Inlet 2	10	51	7.8 1	0.25	59	38
Outlet 2	3.8	23	7.9	0.18	19	6.9
Change	-6.2	-28	+.1	-0.07	-40	-31.1
Percent	62%	55%	1%	28%	68%	82%
Inlet 3	13	55	8.2	0.3	23	23
Outlet 3	4.7	33	7.6	0.18	21	12
Change	-8.3	-22	-0.6	-0.12	-2	-11
Percent Reduction/Gain	64%	40%	7%	40%	9%	48%
Inlet 4	9.9	53	9.2	0.35	39	61
Outlet 4	3.9	29	7.7	0.18	15	7.2
Change	-6	-24	-1.5	-0.17	-24	-53.8
Percent Reduction/Gain	61%	45%	16%	49%	62%	88%
Inlet 5	9.6	53	9.4	0.29	35	56
Outlet 5	3.4	27	7.6	0.17	13	9.4
Change	-6.2	-26	-1.8	-0.12	-22	-46.6
Percent Reduction/Gain	65%	49%	19%	41%	63%	83%
Average Percent Change	53%	52.6%	- %	36%	56%	74.8%

Maximum flow rate 0.136 liters/sec (2.16 GPM, 0.005 cfs)
Storm Duration =50 minutes
Rainfall @ OUC 1.016 cm (0.4 inch), @ SITE, 0.5842 cm (0.23 inch)

Conclusions

While none of the sample events were a perfect combination of a good flow and everything working right, the data collected, and our observations, certainly indicate that the CDS unit is operating as intended and removing significant quantities of debris and suspended materials prior to discharge to surface waters. It was quite impressive to prevent this trash and sediment from washing out into the lagoon during a normal rain.

The phosphorus removals observed for the CDS Unit, as with any BMP of this type, will not have a high degree of accuracy, due to leaching of nutrients from grass, leaves, and other organic debris. If there are no base flows, these leached nutrients will be washed out with runoff and skew sample readings. A much more comprehensive analysis is available in the library of the web site www.stormwater-resources.com.

Future Evaluations

More data are necessary to further evaluate this BMP. Due to the inherent inaccuracies in water quality sampling, additional determination of the efficiency of this type of BMP could be made by conducting a mass loading and sediment evaluation. Much of the sediment collected in this type of BMP is invisible to current testing techniques since it is comprised of large particles that roll along the bottom of the pipe. Yet, known quantities of sediment are being collected.

A previous study of baffle boxes resulted in the same conclusion. Future sediment analysis from the CDS unit could be compared to the baffle box data previously collected. Brevard County will be conducting a sediment evaluation at three baffle box sites over the next 12 months that will provide additional comparison. As time permits, Brevard County will also collect additional sediment data from he CDS unit.